



US009680117B2

(12) **United States Patent**  
**Bartoli et al.**

(10) **Patent No.:** **US 9,680,117 B2**  
(45) **Date of Patent:** **Jun. 13, 2017**

(54) **THIN FILM SMALL MOLECULE ORGANIC PHOTOVOLTAIC SOLAR CELL**

(71) Applicant: **Lehigh University**, Bethlehem, PA (US)

(72) Inventors: **Filbert Joseph Bartoli**, Center Valley, PA (US); **Beibei Zeng**, Bethlehem, PA (US)

(73) Assignee: **LEHIGH UNIVERSITY**

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/781,778**

(22) PCT Filed: **Apr. 3, 2014**

(86) PCT No.: **PCT/US2014/032809**

§ 371 (c)(1),

(2) Date: **Oct. 1, 2015**

(87) PCT Pub. No.: **WO2014/165666**

PCT Pub. Date: **Oct. 9, 2014**

(65) **Prior Publication Data**

US 2016/0049606 A1 Feb. 18, 2016

**Related U.S. Application Data**

(60) Provisional application No. 61/808,407, filed on Apr. 4, 2013.

(51) **Int. Cl.**

**H01L 51/44** (2006.01)

**H01L 51/42** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01L 51/447** (2013.01); **H01L 51/424** (2013.01); **H01L 51/442** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC ..... H01L 51/42–51/448; H01L 31/054; H01L 31/056

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,272,356 A \* 12/1993 Wen ..... H01L 27/146 257/184

2007/0019292 A1 1/2007 Kim et al.  
(Continued)

**OTHER PUBLICATIONS**

Zeng, Beibei, et al. "Absorption enhancement in thin-film organic photovoltaics with double plasmonic structures." IEEE Photonic Society 24th Annual Meeting. 2011.\*

(Continued)

*Primary Examiner* — Allison Bourke

*Assistant Examiner* — William E McClain

(74) *Attorney, Agent, or Firm* — The Belles Group, P.C.

(57) **ABSTRACT**

A thin film organic photovoltaic device or solar cell in one embodiment includes an organic active bilayer and an ultra-thin two-dimensional metallic nanogrid as a transparent conducting electrode which receives incident light. The nanogrid excites surface plasmonic resonances at an interface between the nanogrid and active bilayer from the incident light to enhance photon absorption in the active bilayer below the nanogrid. In another embodiment, spatially separated nanograting electrodes may alternatively be formed by double one-dimensional nanogratings disposed on opposite sides of the organic active bilayer. The spatially separated nanogratings may be oriented perpendicular to each other.

**10 Claims, 18 Drawing Sheets**

